APPLICATION FOR PATENT

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Title: An Antenna Stabilization System for Two Antennas

This application claims priority from U.S. Provisional Application No. 60/419,543 filed on 21st October 2002.

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to antennas of geo-stationary satellites and, in particular, it concerns stabilizing two antennas mounted on a single pedestal.

By way of introduction, various geo-stationary satellites are located at approximately 36,000 Km from the surface of the earth around the equator in a belt known as the "Clark Belt". These satellites serve satellite TV channels and two way communication such as internet, data video conferencing and voice communications. However, not all the TV channels are available from the communication satellites. For example, in the U.S.A. the communication satellites (FSS) which are located at 91 degrees West, 99 Degrees West and 116.8 degrees West do not include the Broadcast TV channels which are provided by the BSS satellites at 101 degrees West, 110 degrees West and 119 degrees West. Typically, on a mobile platform, for example, but not limited to a marine, airborne or ground mobile platform, there is a need to provide both two way communication and to receive broadcast TV channels. Therefore, there is a need to mount two antennas on the mobile platform in order to

provide simultaneous links with two satellites, one for TV Receive Only communications (TVRO) and the other for two way (Tx/Rx) communication.

The simple and common solution is to use two separate pedestal/tracking antenna systems. This solution requires a large amount of space, is not cost effective and there may be interference between the two antennas if they are placed to close together. In addition, two radomes or one large radome are required which takes up additional space and is very expensive.

It is known in the field of antenna alignment to use a single antenna with multiple feeds, such that the antenna receives signals from a plurality of satellites. However, the Regulatory authorities, such as the FCC and ETSI require that the end-user terminal be aligned very accurately with a satellite in order for the end-user to transmit to the satellite. The alignment accuracy required by the Regulatory authorities cannot be achieved using a multiple feed system.

It is also known in the field of antenna alignment systems to mount two antennas on a single pedestal for tracking low earth orbit (LEO) satellites. An example of such a system is taught by U.S. Patent No. 6,310,582 to Uetake, et al. The aforementioned system is suitable for LEO satellites, but is not suitable for tracking two geo-stationary satellites.

There is therefore a need for a cost and space effective stabilization system for two antennas associated with geo-stationary satellites where at least one of the antennas is linearly polarized.

SUMMARY OF THE INVENTION

The present invention is an antenna stabilization system construction and method of operation thereof.

According to the teachings of the present invention there is provided, a system for stabilizing at least two antennas on a mobile platform, the antennas including a first antenna associated with a first geo-stationary satellite and a second antenna associated with a second geo-stationary satellite, the system comprising: (a) an upper alignment system configured for being a common support for the antennas, the upper alignment system having at least one degree of freedom, the upper alignment system including an intermediate element, the upper alignment system being configured for pointing the antennas relative to the intermediate element, such that the angular displacement between the first antenna and the second antenna is substantially matched with the angular displacement between the first geo-stationary satellite and the second geo-stationary satellite; and (b) a lower alignment system mechanically connected to the upper alignment system and the mobile platform, the lower alignment system having three degrees of freedom, the lower alignment system being configured for maintaining the orientation of the intermediate element in order to compensate for rotation of the mobile platform, such that the first antenna and the second antenna are maintained pointing toward the first geo-stationary satellite and the second geo-stationary satellite, respectively.

According to a further feature of the present invention, the three degrees of freedom are rotational degrees of freedom, the three degrees of freedom

including roll, pitch and yaw, the lower alignment system being configured for maintaining the orientation of the intermediate element in order to compensate for movements of yaw, pitch and roll of the mobile platform.

According to a further feature of the present invention, the upper alignment system and the lower alignment system are configured, such that the lower alignment system maintains the orientation of the intermediate element in order that movement of the first antenna and the second antenna is substantially restricted to pointing to satellite of the Clark belt.

According to a further feature of the present invention, the upper alignment system is configured, such that the polarization of the first antenna is adjustable.

According to a further feature of the present invention, the upper alignment system is configured, such that the polarization of the second antenna is adjustable.

According to a further feature of the present invention, the one degree of freedom of the upper alignment system is a rotational degree of freedom configured for setting the cross-elevation of the first antenna and the second antenna.

According to a further feature of the present invention, the upper alignment system, the lower alignment system, the first antenna and the second antenna fit under a single radome.

According to a further feature of the present invention, the upper alignment system and the lower alignment system are configured to provide full hemispherical coverage for the first antenna and the second antenna.

According to the teachings of the present invention there is also provided a method for stabilizing at least two antennas on a mobile platform, the antennas including a first antenna associated with a first geo stationery satellite and a second antenna associated with a second geo stationery satellite, the method comprising the steps of: (a) mechanically connecting the antennas to an element; (b) pointing the antennas relative to each other such that the angular displacement between the first antenna and the second antenna is matched with the angular displacement between the first geo-stationary satellite and the geo-stationary second satellite; and (c) maintaining the orientation of the element in order to compensate for rotation of the mobile platform, such that the first antenna and the second antenna are maintained pointing toward the first geo-stationary satellite and the second geo-stationary satellite, respectively.

According to a further feature of the present invention, the step of maintaining includes at least one of a roll adjustment, a pitch adjustment and a yaw adjustment in order to compensate for movements of roll, pitch and yaw of the mobile platform, respectively.

According to a further feature of the present invention, the step of maintaining is performed, such that movement of the first antenna and the second antenna is restricted to pointing to satellite of the Clark belt.

According to a further feature of the present invention, there is also provided the step of adjusting the polarization of the first antenna.

According to a further feature of the present invention, there is also provided the step of adjusting the polarization of the second antenna.

According to a further feature of the present invention, there is also provided the step of disposing the antennas in a single radome.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is a schematic isometric view of an antenna stabilization system that is constructed and operable in accordance with a preferred embodiment of the present invention;

Fig. 2 is a schematic view of the system of Fig. 1 mounted on a mobile platform; and

Fig. 3 is an isometric view of an antenna stabilization system that is constructed and operable in accordance with a most preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is an antenna stabilization system construction and method of operation thereof.

The principles and operation of an antenna stabilization system according to the present invention may be better understood with reference to the drawings and the accompanying description.

Reference is now made to Figs. 1 and 2. Fig. 1 is a schematic isometric view of an antenna stabilization system **10** that is constructed and operable in accordance with a preferred embodiment of the present invention. Fig. 2 is a schematic view of antenna stabilization system **10** mounted on a mobile platform **16**. Antenna stabilization system **10** is a system for stabilizing two antennas **12**, **14** on a mobile platform **16**. Antenna **12** is associated with a geo-stationary satellite **18**. Antenna **14** is associated with a geo-stationary satellite **20**. Antenna stabilization system **10** includes a lower alignment system **22** and an upper alignment system **24**. Lower alignment system **22** is mechanically connected to mobile platform **16**. Lower alignment system **22** includes an intermediate element **26**. Intermediate element **26** is generally an elongated element. Lower alignment system **22** is mechanically connected to upper alignment system **24** via intermediate element **26**. Intermediate element **26** of upper alignment system **24** is a common support for antenna **12** and antenna **14**.

Lower alignment system **22** has three rotational degrees of freedom including a roll adjustment **34**, a pitch adjustment **36** and a yaw adjustment **38**

for adjusting the orientation of intermediate element **26**, as described in more detail below.

Upper alignment system **24** has three rotational degree of freedom **28** **30** **32**. Antenna **12** is mechanically connected to one end of intermediate element **26** via degree of freedom **28**. Antenna **14** is mechanically connected to one end of intermediate element **26** via degree of freedom **30** and degree of freedom **32**. The axis of rotation of degree of freedom **28** and degree of freedom **30** are perpendicular to the direction of elongation of intermediate element **26**. The axis of rotation of degree of freedom **32** is parallel to the direction of elongation of intermediate element **26**. Degree of freedom **28** and degree of freedom **30** are configured for adjusting the polarization of antenna **12** and antenna **14**, respectively. If antenna **12** and/or antenna **14** are not linearly polarized, then degree of freedom **28** and degree of freedom **30** are not needed, respectively. for example, but not limited to when antenna satellite **20** is a TVRO satellite, degree of freedom **30** is generally not needed.

Lower alignment system **22** and upper alignment system **24** include motors (not shown) for adjusting the degrees of freedom of antenna stabilization system **10**. The motors are driven by a servo driver unit **40** (SDU) motor driver.

The operation of antenna stabilization system **10** is best described by first assuming that mobile platform **16** is completely stationary without tilting, rocking, or turning. In this scenario, lower alignment system **22** is configured by adjusting roll adjustment **34**, pitch adjustment **36** and yaw adjustment **38**,

such that the direction of elongation of intermediate element **26** is perpendicular to a plane which includes all the satellites in the Clark Belt and antenna **12** is pointing toward satellite **18**. Therefore, as degree of freedom **32** is parallel to the direction of elongation of intermediate element **26**, the movement of antenna **14** is restricted, such that antenna **14** is only able to point to satellites in the Clark belt. Degree of freedom **32** is adjusted, such that antenna **14** points toward satellite **20**. In other words, degree of freedom **32** substantially matches the angular displacement between antenna **12** and antenna **14** with the angular displacement between the satellite **18** and satellite **20**. The term "substantially matches" is defined herein such that the angular displacement is matched well enough, such that antenna **12** can communicate with satellite **18** and antenna **14** can communicate with satellite **20**. The angular displacement between satellite **18** and satellite **20** is defined as the angle between two lines, the first line connecting satellite **18** and a point on antenna stabilization system **10**, the second line connecting satellite **20** and the same point of antenna stabilization system **10**. The angular displacement between antenna **12** and antenna **14** is defined as the angle between a "line of sight" of antenna **12** and a "line of sight" of antenna **14**. The term "line of sight" is defined herein as a line joining the communication center of an antenna and the communication center of a satellite, the antenna and the satellite being aligned for peak communication. In other words, degree of freedom **32** is configured for setting the cross-elevation of antenna **12** and antenna **14**.

The operation of antenna stabilization system **10** is now described by assuming that mobile platform **16** is rotating. Rotating is defined herein as to include tilting, rocking, or turning of mobile platform **16**. Antenna stabilization system **10** also includes an inertial measurement unit **42** (IMU) for measuring movement of mobile platform **16**. Antenna stabilization system **10** also includes a controller **44**. Controller **44** is configured for processing the measurements of inertial measurement unit **42** as well as running algorithms for continuous peak signal-strength detection. Therefore, measurements from inertial measurement unit **42** provide data for coarse adjustment of lower alignment system **22** and upper alignment system **24**, while signal-strength algorithms provide data for fine adjustment of lower alignment system **22** and upper alignment system **24**. Therefore, the signal strength algorithms enable the accuracy and therefore the cost of inertial measurement unit **42**, lower alignment system **22** and upper alignment system **24** to be reduced. U.S. Patent No. 6,608,950 to Naym, et al. describes a novel system for adjusting for polarization using auto-correlation. It will be appreciated by those ordinarily skilled in the art that the auto-correlation method can be used for aligning roll of antenna stabilization system **10**. Methods for adjusting yaw and pitch using signal strength techniques are known by those skilled in the art. Controller **44** is configured for instructing servo driver unit **40** to adjust the motors of lower alignment system **22** and upper alignment system **24** in order to adjust for movements of mobile platform **16**. Therefore, lower alignment system **22** is configured for maintaining the orientation of intermediate element **26** in order

to compensate for rotation of mobile platform **16** relative to satellite **18** and satellite **20**, such that the direction of elongation of intermediate element **26** is perpendicular to a plane which includes all the satellites in the Clark Belt and antenna **12** is pointing toward satellite **18**. In other words, lower alignment system **22** is configured for maintaining intermediate element **26** in a constant angular and rotational position. The angular displacement between antenna **12** and antenna **14** does not need to be adjusted by adjusting degree of freedom **32**. This is because the angular displacement between satellite **18** and satellite **20** does not alter significantly enough to effect communication between antennas **12**, **14** and satellites **18**, **20**, respectively. The angular displacement between antenna **12** and antenna **14** only needs to be adjusted when there is a significant change in longitude or latitude of mobile platform **16**, which effects communication.

Therefore, adjustment of at least one of roll adjustment **34**, pitch adjustment **36** and yaw adjustment **38** of lower alignment system **22** is enough to compensate for at least one of roll, pitch and yaw movement of mobile platform **16** relative to satellites **18**, **20**, such that antenna **12** and antenna **14** are maintained pointing toward satellite **18** and satellite **20**, respectively, without needing to adjust upper alignment system **24**. Therefore, one of the important advantages of antenna stabilization system **10** is that only the degrees of freedom of lower alignment system **22** need to be adjusted to realign both antenna **12** and antenna **14** toward satellite **18** and satellite **20**, respectively. Therefore, degree of freedom **28**, degree of freedom **30** and degree of

freedom **32** of upper alignment system **24** only need to have a low-dynamic response, for example, for selecting a different pair of satellites or for accurate correction and/or compensation of slight variations of the angular displacement of satellite **18** and satellite **20** due to geographical longitudinal or latitudinal movement of mobile platform **16**. Roll adjustment **34**, pitch adjustment **36** and yaw adjustment **38** of lower alignment system **22** need to have a high dynamic response, typically having a velocity up to 30 degrees per second, and an acceleration of up to 30 degrees per second per second. Antenna stabilization system **10** typically has a pointing accuracy better than 0.3 degrees RMS. Additionally, antenna stabilization system **10** typically has a resolution of less than 0.01 degree, enabling very smooth operation and high quality continuous step-track.

The rotational requirement of the degrees of freedom of antenna stabilization system **10** are typically as follows. Yaw adjustment **38** is continuous. Pitch adjustment **36** is from minus 10 degrees to plus 90 degrees. Roll adjustment **34** is from minus 60 degrees to plus 60 degrees. Degree of freedom **28** and degree of freedom **30** are both from minus 90 degrees to plus 90 degrees. Degree of freedom **32** is from minus 90 degrees to plus 90 degrees.

The system and method of the present invention also includes the following advantages. First, antenna stabilization system **10** enables selection of any pair of satellites. Second, antenna stabilization system **10** enables antenna **12** and antenna **14** to be pointed toward a single satellite or two very close satellites. Third, antenna stabilization system **10** including antenna **12** and

antenna **14** fits under a single radome **52**. Fourth, there is no communication blockage between antenna **12** and antenna **14**. Fifth, the lower alignment system **22** and upper alignment system **24** are configured to provide full hemispherical coverage for the antenna **12** and antenna **14**, typically down to minus 10 degrees elevation (pitch) and continuous azimuth (yaw) rotation.

Reference is now made to Fig. 3, which is an isometric view of an antenna stabilization system **46** that is constructed and operable in accordance with a most preferred embodiment of the present invention. Antenna stabilization system **46** is the same as antenna stabilization system **10** (Fig. 1) except for the following differences. Pitch adjustment **36** and roll adjustment **34** are both disposed very close to intermediate element **26**. Therefore, lower alignment system **22** has a curved elongated element **48** disposed between pitch adjustment **36** and yaw adjustment **38** in order that movement of antennas **12**, **14** is not restricted, such that antenna stabilization system **10** provides full hemispherical coverage for antenna **12** and antenna **14**. Additionally, upper alignment system **24** includes a counterweight arrangement **50** disposed on intermediate element **26** in order to reduce the load on the motors (not shown) of antenna stabilization system **46**.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and sub-combinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the

prior art which would occur to persons skilled in the art upon reading the foregoing description.